INTERFEROMETRIC MEASUREMENTS OF CERTAIN LINES IN THE SPECTRUM OF BROMINE

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Plates XIV and XV

ABSTRACT. Using a Fabry-Perot Etalon in conjunction with a Hilger Quartz Littrow Spectrograph the wave-lengths of nine lines in the spectrum of Bromine II have been measured. Vacuum Copper Arc lines λλ 5153.235 and 4651.124 have been used as standards.

The measured lines include the super-quintet $5s\ ^5S - 5p\ ^5P$ of Br II. The intervals of the $5p\ ^5P$ level are thus determined accurately.

INTRODUCTION

Determination of the wave-lengths of spectral lines to a high degree of accuracy have been successfully carried out by a number of investigators, Babcock, Burns, McLennan, Meggers, Jackson[1] and others using high resolving power apparatus such as the Fabry-Perot Etalon. The fundamental standard of wave-length that is almost invariably adopted is that of the red Cadmium Line λ 6438.4696 and, in terms of this, the wave-lengths of a very large number of Fe, Ne, He, lines have been measured interferometrically for use as subsidiary standards in Spectroscopic work. Besides the use of such measurements as subsidiary standards, accuracy in the determination of wave-lengths is highly desirable in investigations on the Analysis of Spectra and the identification of spectral lines.

In the course of the work on the analysis of the spectrum of Bromine carried out in this Laboratory, the need for accurate wave-lengths of as many lines of Bromine as possible, particularly of those belonging to Br. II, Br. III has been felt. The present paper deals with the measurement of a few lines, as produced in an ordinary vacuum tube and determined by a 10-mm. Fabry-Perot Etalon in conjunction with a Hilger large Quartz Littrow Spectrograph. The general procedure and method of calculation followed in this work are essentially the same as that of Babcock and of MacLennan and described in detail by the latter,[1] in investigations on the Auroral Green Line.

Theory of the wave-length determination :—It can be easily shown from the theory of the Etalon that for two wave-lengths λ_x and λ, the difference $(m+\delta)$ in the order of interference for normal incidence is given by[2]

$$\Delta\nu=(\nu_x-\nu)=\frac{1}{\mu_x}\left[\frac{m+\delta}{2t}-\nu\Delta\mu\right] \qquad \ldots \quad (1)$$

where ν_x and ν are the respective frequencies and μ_x and μ the refractive indices; m and δ are the integral and fractional parts of the order of the interference. In utilising this equation, two lines (the wavelengths of which are known by interferometric methods) are chosen as standards say λ_x and λ. From the calculated values of the refractive indices for the two lines and the approximate value of $2t$, the double thickness of the Etalon, supplied by the manufacturers the value of $(m+\delta)$ is first approximately calculated. This, however, gives the value of m, the integral part of the order of interference accurately.

To find δ correctly, the interference patterns for the two standards are measured. If d_p and d_q be the diameters of any two rings p and q of the system formed by the wave-length λ then a is given by [2]

$$a=\frac{(p-1)d_q^2-(q-1)d_p^2}{d_p^2-d_q^2} \qquad \ldots \quad (2)$$

with a similar expression for a_x corresponding to λ_x.

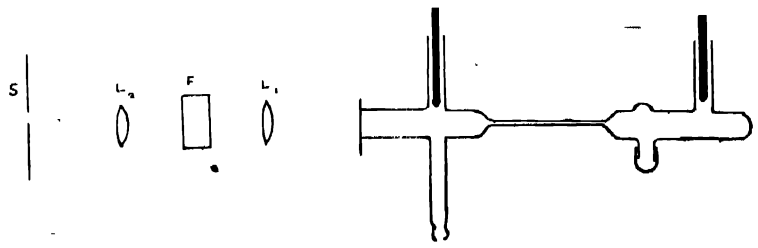
Then δ is calculated from the equation

$$\delta=(a_x-a) \text{ or } (1+a_x)-a.$$

Hence knowing $(m+\delta)$ accurately, the value of $2t$ is determined with precision from equation (1).

The wave-length of any other required line can then be estimated from this value of $2t$ from the observations of the fringe pattern of that line, using a single standard.

EXPERIMENTAL



A—Discharge tube
L_1—Collimating lens
F—Fabry-Perot Etalon
L_2—Condensing lens
S—Slit of the spectrograph

FIGURE 1. Optical Arrangement

Fig. a

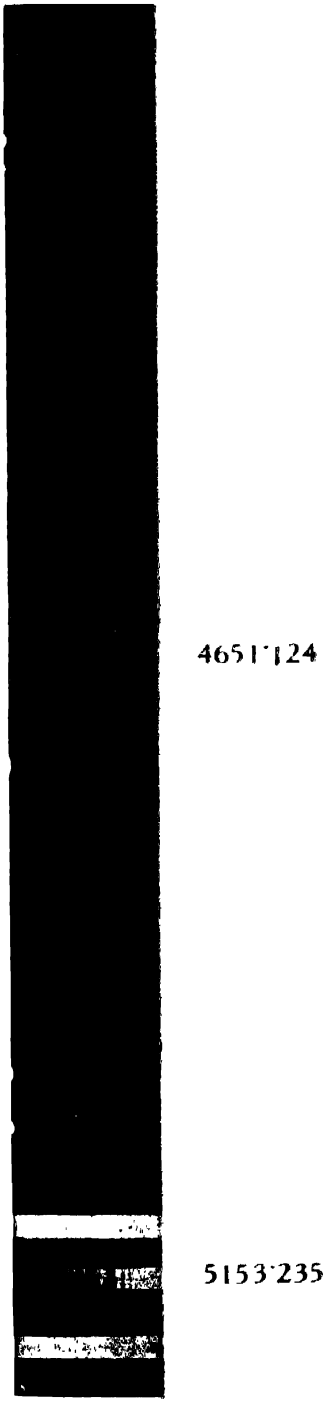


Fig. b

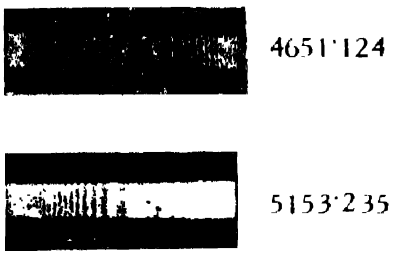


Fig. a. The patterns of the Vaccum Copper arc Spectrum.
Fig. b. Fringe System of λ 5153·235 and of λ 4651·124 of the Copper arc shown enlarged.

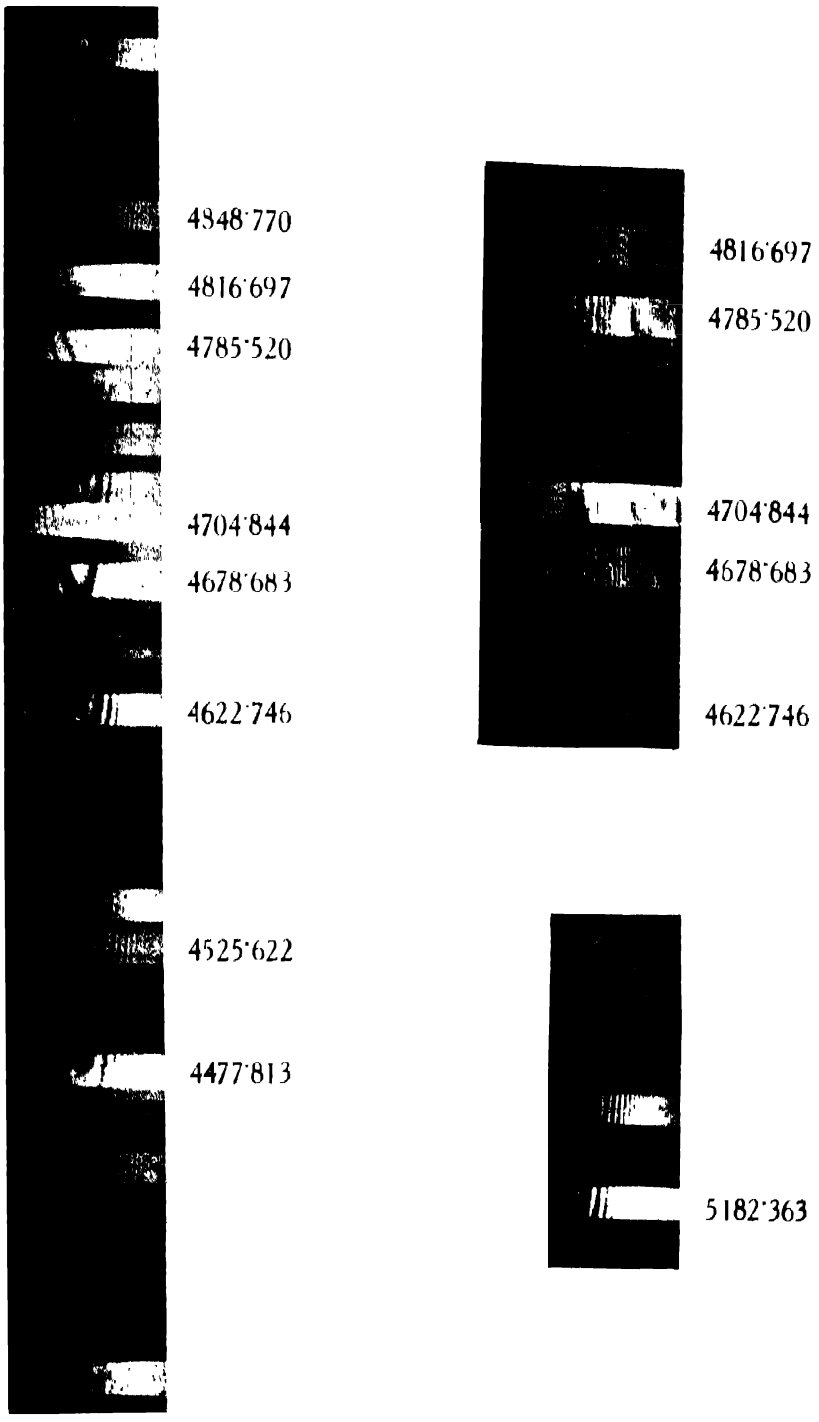


Fig. c. Patterns in the Spectrum of Bromine.

The general optical arrangement is shown diagrammatically in figure 1. Fringe patterns are first obtained for the two lines of Copper λ 5153.235 and λ 4651.124, which served as standards[3] for determining 2t. These lines are excited in a vacuum arc with water-cooled electrodes of about 6 mms. diam. The gap between the electrodes is adjusted to be five to seven millimeters, during the actual exposure. The arc is fed by a current of about 2.5 to 3 amperes from a 220-volt D.C. mains. Light from the arc is rendered parallel by the glass achromatic lens L_1 of about 12 cms. focal length and allowed to strike the parallel faces of the etalon arranged immediately in front of it. On emergence from the plate the light is focussed on to the slit of the spectrograph by another similar lens of shorter focal length. The etalon is so adjusted that the pattern consists of rings on both sides of the centre. With a good alignment of the optical parts exposures of about a minute on Ilford special rapid panchromatic plates gave good pictures of the patterns of the Copper arc lines.

For photographing the Bromine lines an ordinary discharge tube of the H-type is employed. The central capillary portion is about 2 mms. wide and 15 cms long. A bulb at one end of the tube contains a small quantity of copper bromide. Periodic heating of the bulb is found necessary to maintain sufficient pressure of Bromine in the capillary. The discharge tube is continuously evacuated by a Gaede two-stage pump connected to it. To prevent vapours from entering the pump, tubes of calcium chloride, caustic potash and phosphorous pentoxide are inserted between the pump and the discharge tube. The tube is excited by a 1/4 K.W. transformer, the primary being fed by 220 volt A.C. and a current of about .6 to .8 of an ampere. The length of the series spark gap is adjusted for a somewhat low intensity of excitation in order that the lines of Br. II might be emitted strongly. The discharge under these conditions is bluish green. Exposures of 2 to 3 hours are given to bring about the fringe pattern clearly. In all the above experiments the slit of the spectrograph is 0.29 mm. To identify the lines of Bromine, preliminary experiments are made with narrow and wide slit widths to photograph the spectra before and after filling the bulb with copper bromide, using Fe and Cu arc comparison spectra for purposes of measurement.

Plates XIV and XV show the fringe patterns of the copper arc lines 5153 and 4651 and of those of the lines of Bromine that have been measured in this work.

The fringe systems are measured with a Hilger photo-measuring micrometer reading to .001 mm. The point of intersection of the cross-wire has been set symmetrically with respect to the width of the fringe and measurements are made along the length of the diameters of the successive fringes. Each line is measured a number of times in the forward and backward directions ; the average of the readings as measured on three different plates is finally adopted. The results of observation are given in tabular form along with the optical data supplied by the makers of the Etalon in the following section. The calculation of 2t and of the

wave-length of one of the lines of Bromine are shown in detail as a typical illustration of the method. The wave-lengths of the remaining lines which are similarly calculated are entered in the table at the end with the other data. The last column in this table gives the wave-lengths as determined by the use of the second available copper standard to serve as a check on the determination. The agreement between the two independently obtained values is satisfactory.

CALCULATION AND RESULTS

Thickness of the Etalon as supplied by Hilger =9.924 mms.

The two Copper Arc standards employed have the values,

$\lambda = 5153.235 \quad \mu = 1.51229 \quad \nu = 19405.290$

$\lambda_x = 4651.124 \quad \mu_x = 1.51578 \quad \nu_x = 21500.175$

$\Delta\mu = 0.00349 \quad \Delta\nu = 2094.885.$

The mean values of a and a_x obtained from the measurement of the fringe systems of two lines are

$a = .989 \quad a_x = 1.286$

$\delta = .297.$

The integral part deduced from equation (1) is 6436. Hence the value of the double thickness 2t is found to be 1.98463. This value is used in the subsequent calculation.

For the Bromine line the values are,

$\lambda_x = 4816.71 \quad \mu_x = 1.51451 \quad \nu_x = 20761.057.$

For the Cu standard,

$\lambda = 5153.235 \quad \mu = 1.51229 \quad \nu = 19405.290.$

Approx. wave-length of Br. lines	Refr. Index	a_x	δ	Approx. $(m+\delta)$	Integral Part m	Final $(m+\delta)$	$\Delta\nu$	Final Wave-Length	
								Standard $\lambda=5153$	Standard $\lambda=4651$
5182.36	1.51212	1.048	.941	333.931	333	333.941	109.065	5182.362	5182.363
4848.75	1.51427	1.405	.416	3738.688	3738	3738.416	1218.490	4848.770	4848.770
4816.71	1 51451	.629	.640	4160.484	4160	4160.640	1355 818	4816.696	4816.698
4785.50	1.51474	.710	.721	4576.975	4576	4576.721	1491.082	4785.520	4785.519
4704.86	1.51535	.788	.799	5679.585	5679	5679.799	1849.401	4704.844	4704.844
4678 69	1.51556	.981	992	6045 852	6045	6045 992	1968.256	4678 681	4678 684
4622.75	1.51601	1.278	.289	6843.247	6843	6843.289	2226.869	4622.746	4622.746
4525.60	1.51684	1.354	.365	8276.703	8276	8276 365	2691.117	4525.623	4525.622
4477.80	1.51726	1.528	.539	9005.736	9005	9005.539	2927.043	4477.813	4477.813

Mean values of a obtained from measurements on the diameters of the fringes are

for the Cu standard $= .989$

for the Br line $= .629$

$$\delta = (1 + a_x) - a = .640.$$

The integral part m from equation (1) is 4160.

Hence $$\Delta\nu = 1355.818 \text{ cms.}^{-1}$$

and $$\lambda = 4816.696 \text{ A.U.}$$

The value of same line calculated with the other Copper standard is found to be 4816.698, agreeing very closely with the above.

The above table gives the data obtained with the other lines. The above measurements include those of three lines $\lambda\lambda$ 4816.697, 4785.520, and 4704.844 which form the combination $5s^5S_2 - 5p^5P_{1,2,3}$ of Br II as identified by Bloch.[4] The intervals $5p^5P$ are thus known now accurately to be $^5P_1 - {}^5P_2 = 135.20$, and $^5P_2 - {}^5P_3 = 358.27$ cms.$^{-1}$

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